National Semiconductor

March 1995

LM1875 20W Audio Power Amplifier

General Description

The LM1875 is a monolithic power amplifier offering very low distortion and high quality performance for consumer audio applications.

The LM1875 delivers 20 watts into a 4Ω or 8Ω load on ±25V supplies. Using an 8Ω load and ±30V supplies, over 30 watts of power may be delivered. The amplifier is designed to operate with a minimum of external components. Device overload protection consists of both internal current limit and thermal shutdown.

The LM1875 design takes advantage of advanced circuit techniques and processing to achieve extremely low distortion levels even at high output power levels. Other outstanding features include high gain, fast slew rate and a wide power bandwidth, large output voltage swing, high current capability, and a very wide supply range. The amplifier is internally compensated and stable for gains of 10 or greater.

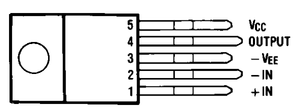
Features

- Up to 30 watts output power
- A_{VO} typically 90 dB
- Low distortion: 0.015%, 1 kHz, 20 W
- Wide power bandwidth: 70 kHz
- Protection for AC and DC short circuits to ground
- Thermal protection with parole circuit
- High current capability: 4A
- Wide supply range 16V-60V
- Internal output protection diodes
- 94 dB ripple rejection
- Plastic power package TO-220

Applications

- High performance audio systems
- Bridge amplifiers
- Stereo phonographs
- Servo amplifiers
- Instrument systems

Connection Diagram

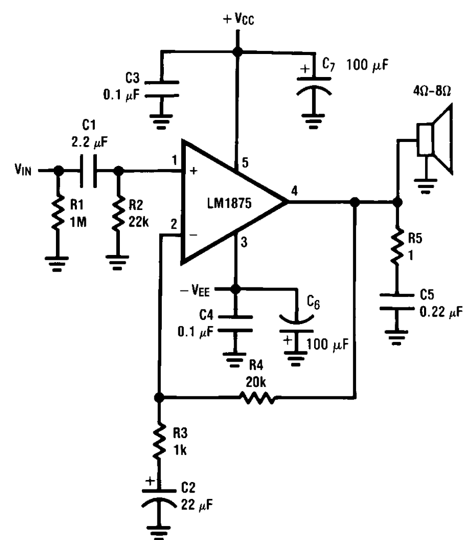


TL/H/5030–1

Front View

Order Number LM1875T
See NS Package Number T05B

Typical Applications



TL/H/5030–2

 TL/H/5030 RRD-B30M75/Printed in U. S. A.

Absolute Maximum Ratings

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage	60V
Input Voltage	$-V_{EE}$ to V_{CC}
Storage Temperature	-65°C to $+150$°C
Junction Temperature	150°C
Lead Temperature (Soldering, 10 seconds)	260°C
θ_{JC}	3°C
θ_{JA}	73°C

Electrical Characteristics

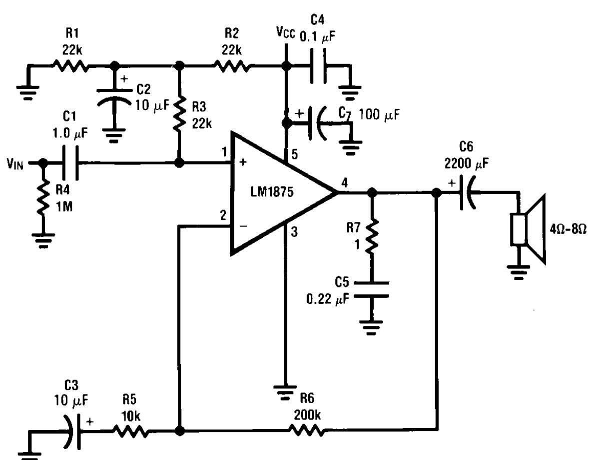
$V_{CC} = +25V$, $-V_{EE} = -25V$, $T_{AMBIENT} = 25$°C, $R_L = 8\Omega$, $A_V = 20$ (26 dB), $f_o = 1$ kHz, unless otherwise specified.

Parameter	Conditions	Typical	Tested Limits	Units
Supply Current	$P_{OUT} = 0W$	70	100	mA
Output Power (Note 1)	THD = 1%	25		W
THD (Note 1)	$P_{OUT} = 20W$, $f_o = 1$ kHz	0.015		%
	$P_{OUT} = 20W$, $f_o = 20$ kHz	0.05	0.4	%
	$P_{OUT} = 20W$, $R_L = 4\Omega$, $f_o = 1$ kHz	0.022		%
	$P_{OUT} = 20W$, $R_L = 4\Omega$, $f_o = 20$ kHz	0.07	0.6	%
Offset Voltage		±1	±15	mV
Input Bias Current		±0.2	±2	μA
Input Offset Current		0	±0.5	μA
Gain-Bandwidth Product	$f_o = 20$ kHz	5.5		MHz
Open Loop Gain	DC	90		dB
PSRR	V_{CC}, 1 kHz, 1 Vrms	95	52	dB
	V_{EE}, 1 kHz, 1 Vrms	83	52	dB
Max Slew Rate	20W, 8Ω, 70 kHz BW	8		V/μs
Current Limit	$V_{OUT} = V_{SUPPLY} - 10V$	4	3	A
Equivalent Input Noise Voltage	$R_S = 600\Omega$, CCIR	3		μVrms

Note 1: Assumes the use of a heat sink having a thermal resistance of 1°C/W and no insulator with an ambient temperature of 25°C. Because the output limiting circuitry has a negative temperature coefficient, the maximum output power delivered to a 4Ω load may be slightly reduced when the tab temperature exceeds 55°C.

Typical Applications (Continued)

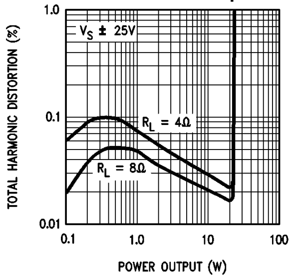
Typical Single Supply Operation



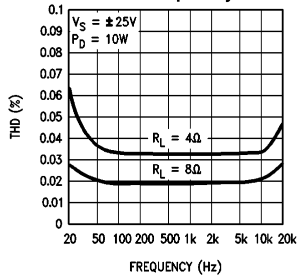
TL/H/5030–3

Typical Performance Characteristics

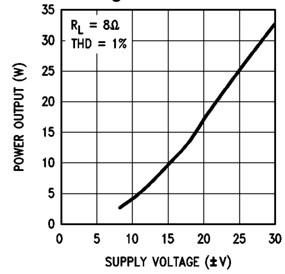
THD vs Power Output



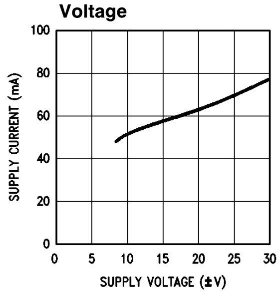
THD vs Frequency



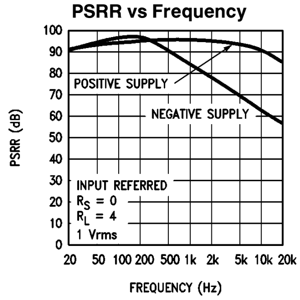
Power Output vs Supply Voltage



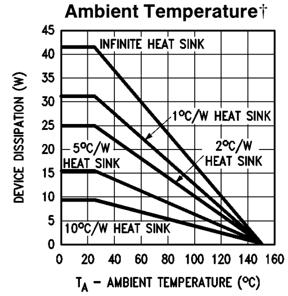
Supply Current vs Supply Voltage



PSRR vs Frequency

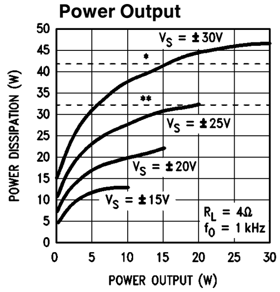


Device Dissipation vs Ambient Temperature†

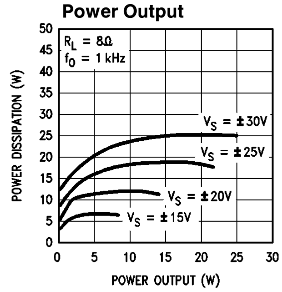


†$\phi_{INTERFACE}$ = 1°C/W.
See Application Hints.

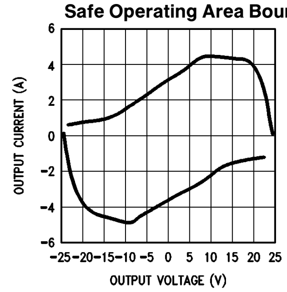
Power Dissipation vs Power Output



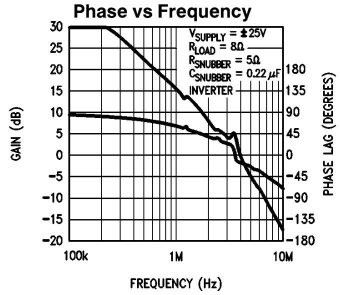
Power Dissipation vs Power Output



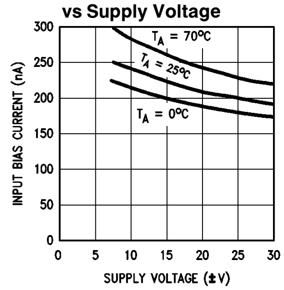
I_{OUT} vs V_{OUT}-Current Limit/ Safe Operating Area Boundary



Open Loop Gain and Phase vs Frequency



Input Bias Current vs Supply Voltage

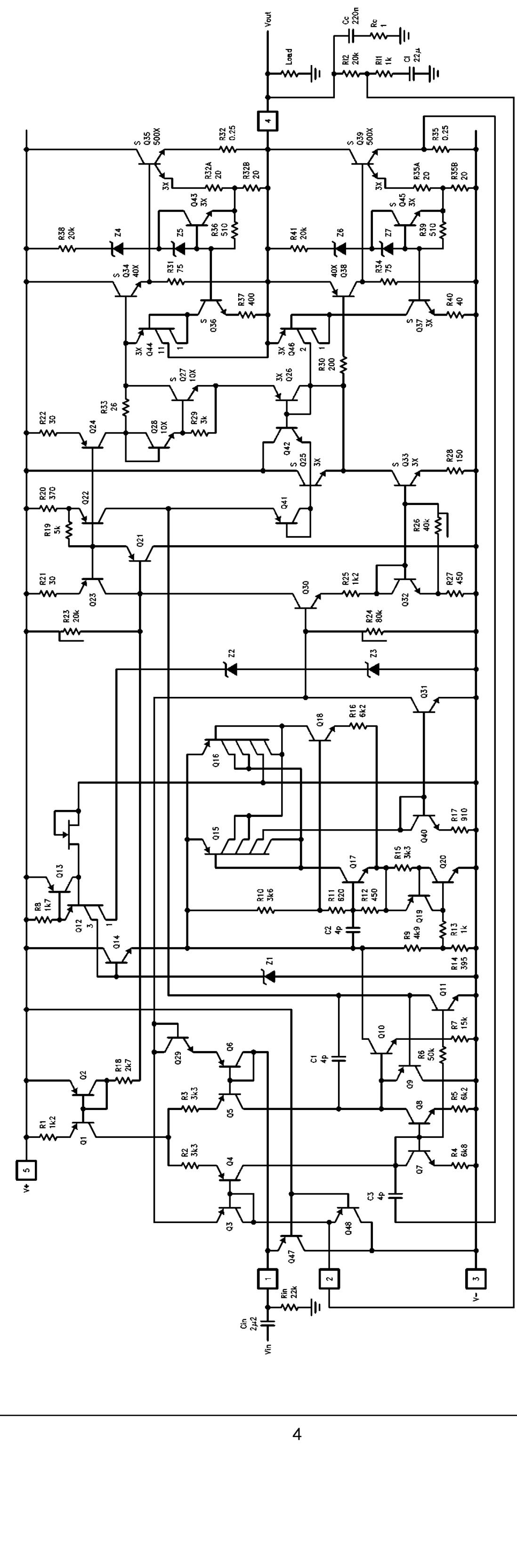


TL/H/5030–4

*Thermal shutdown with infinite heat sink

**Thermal shutdown with 1°C/W heat sink

Schematic Diagram



TL/H/5030–5

Application Hints

STABILITY

The LM1875 is designed to be stable when operated at a closed-loop gain of 10 or greater, but, as with any other high-current amplifier, the LM1875 can be made to oscillate under certain conditions. These usually involve printed circuit board layout or output/input coupling.

Proper layout of the printed circuit board is very important. While the LM1875 will be stable when installed in a board similar to the ones shown in this data sheet, it is sometimes necessary to modify the layout somewhat to suit the physical requirements of a particular application. When designing a different layout, it is important to return the load ground, the output compensation ground, and the low level (feedback and input) grounds to the circuit board ground point through separate paths. Otherwise, large currents flowing along a ground conductor will generate voltages on the conductor which can effectively act as signals at the input, resulting in high frequency oscillation or excessive distortion. It is advisable to keep the output compensation components and the 0.1 µF supply decoupling capacitors as close as possible to the LM1875 to reduce the effects of PCB trace resistance and inductance. For the same reason, the ground return paths for these components should be as short as possible.

Occasionally, current in the output leads (which function as antennas) can be coupled through the air to the amplifier input, resulting in high-frequency oscillation. This normally happens when the source impedance is high or the input leads are long. The problem can be eliminated by placing a small capacitor (on the order of 50 pF to 500 pF) across the circuit input.

Most power amplifiers do not drive highly capacitive loads well, and the LM1875 is no exception. If the output of the LM1875 is connected directly to a capacitor with no series resistance, the square wave response will exhibit ringing if the capacitance is greater than about 0.1 µF. The amplifier can typically drive load capacitances up to 2 µF or so without oscillating, but this is not recommended. If highly capacitive loads are expected, a resistor (at least 1Ω) should be placed in series with the output of the LM1875. A method commonly employed to protect amplifiers from low impedances at high frequencies is to couple to the load through a 10Ω resistor in parallel with a 5 µH inductor.

DISTORTION

The preceding suggestions regarding circuit board grounding techniques will also help to prevent excessive distortion levels in audio applications. For low THD, it is also necessary to keep the power supply traces and wires separated from the traces and wires connected to the inputs of the LM1875. This prevents the power supply currents, which are large and nonlinear, from inductively coupling to the LM1875 inputs. Power supply wires should be twisted together and separated from the circuit board. Where these wires are soldered to the board, they should be perpendicular to the plane of the board at least to a distance of a couple of inches. With a proper physical layout, THD levels at 20 kHz with 10W output to an 8Ω load should be less than 0.05%, and less than 0.02% at 1 kHz.

CURRENT LIMIT AND SAFE OPERATING AREA (SOA) PROTECTION

A power amplifier's output transistors can be damaged by excessive applied voltage, current flow, or power dissipation. The voltage applied to the amplifier is limited by the design of the external power supply, while the maximum current passed by the output devices is usually limited by internal circuitry to some fixed value. Short-term power dissipation is usually not limited in monolithic audio power amplifiers, and this can be a problem when driving reactive loads, which may draw large currents while high voltages appear on the output transistors. The LM1875 not only limits current to around 4A, but also reduces the value of the limit current when an output transistor has a high voltage across it.

When driving nonlinear reactive loads such as motors or loudspeakers with built-in protection relays, there is a possibility that an amplifier output will be connected to a load whose terminal voltage may attempt to swing beyond the power supply voltages applied to the amplifier. This can cause degradation of the output transistors or catastrophic failure of the whole circuit. The standard protection for this type of failure mechanism is a pair of diodes connected between the output of the amplifier and the supply rails. These are part of the internal circuitry of the LM1875, and needn't be added externally when standard reactive loads are driven.

THERMAL PROTECTION

The LM1875 has a sophisticated thermal protection scheme to prevent long-term thermal stress to the device. When the temperature on the die reaches 170°C, the LM1875 shuts down. It starts operating again when the die temperature drops to about 145°C, but if the temperature again begins to rise, shutdown will occur at only 150°C. Therefore, the device is allowed to heat up to a relatively high temperature if the fault condition is temporary, but a sustained fault will limit the maximum die temperature to a lower value. This greatly reduces the stresses imposed on the IC by thermal cycling, which in turn improves its reliability under sustained fault conditions.

Since the die temperature is directly dependent upon the heat sink, the heat sink should be chosen for thermal resistance low enough that thermal shutdown will not be reached during normal operation. Using the best heat sink possible within the cost and space constraints of the system will improve the long-term reliability of any power semiconductor device.

POWER DISSIPATION AND HEAT SINKING

The LM1875 must always be operated with a heat sink, even when it is not required to drive a load. The maximum idling current of the device is 100 mA, so that on a 60V power supply an unloaded LM1875 must dissipate 6W of power. The 54°C/W junction-to-ambient thermal resistance of a TO-220 package would cause the die temperature to rise 324°C above ambient, so the thermal protection circuitry will shut the amplifier down if operation without a heat sink is attempted.

Application Hints (Continued)

In order to determine the appropriate heat sink for a given application, the power dissipation of the LM1875 in that application must be known. When the load is resistive, the maximum average power that the IC will be required to dissipate is approximately:

$$P_{D(MAX)} \approx \frac{V_S^2}{2\pi^2 R_L} + P_Q$$

where V_S is the total power supply voltage across the LM1875, R_L is the load resistance, and P_Q is the quiescent power dissipation of the amplifier. The above equation is only an approximation which assumes an "ideal" class B output stage and constant power dissipation in all other parts of the circuit. The curves of "Power Dissipation vs Power Output" give a better representation of the behavior of the LM1875 with various power supply voltages and resistive loads. As an example, if the LM1875 is operated on a 50V power supply with a resistive load of 8Ω, it can develop up to 19W of internal power dissipation. If the die temperature is to remain below 150°C for ambient temperatures up to 70°C, the total junction-to-ambient thermal resistance must be less than

$$\frac{150°C - 70°C}{19W} = 4.2°C/W.$$

Using $\theta_{JC} = 2°C/W$, the sum of the case-to-heat-sink interface thermal resistance and the heat-sink-to-ambient thermal resistance must be less than 2.2°C/W. The case-to-heat-sink thermal resistance of the TO-220 package varies with the mounting method used. A metal-to-metal interface will be about 1°C/W if lubricated, and about 1.2°C/W if dry.

If a mica insulator is used, the thermal resistance will be about 1.6°C/W lubricated and 3.4°C/W dry. For this example, we assume a lubricated mica insulator between the LM1875 and the heat sink. The heat sink thermal resistance must then be less than

$$4.2°C/W - 2°C/W - 1.6°C/W = 0.6°C/W.$$

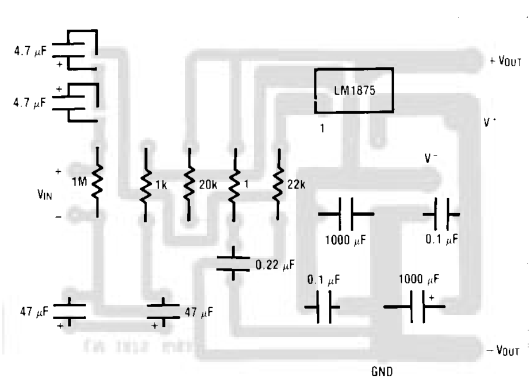
This is a rather large heat sink and may not be practical in some applications. If a smaller heat sink is required for reasons of size or cost, there are two alternatives. The maximum ambient operating temperature can be reduced to 50°C (122°F), resulting in a 1.6°C/W heat sink, or the heat sink can be isolated from the chassis so the mica washer is not needed. This will change the required heat sink to a 1.2°C/W unit if the case-to-heat-sink interface is lubricated.

Note: When using a single supply, maximum transfer of heat away from the LM1875 can be achieved by mounting the device directly to the heat sink (tab is at ground potential); this avoids the use of a mica or other type insulator.

The thermal requirements can become more difficult when an amplifier is driving a reactive load. For a given magnitude of load impedance, a higher degree of reactance will cause a higher level of power dissipation within the amplifier. As a general rule, the power dissipation of an amplifier driving a 60° reactive load (usually considered to be a worst-case loudspeaker load) will be roughly that of the same amplifier driving the resistive part of that load. For example, a loudspeaker may at some frequency have an impedance with a magnitude of 8Ω and a phase angle of 60°. The real part of this load will then be 4Ω, and the amplifier power dissipation will roughly follow the curve of power dissipation with a 4Ω load.

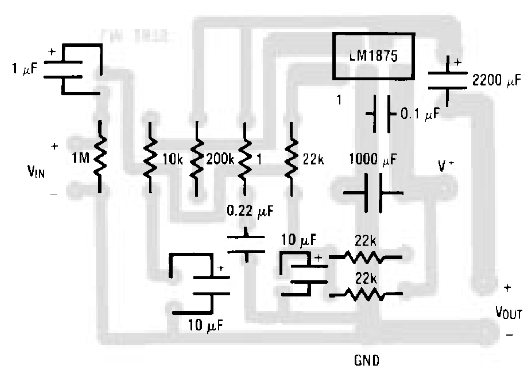
Component Layouts

Split Supply



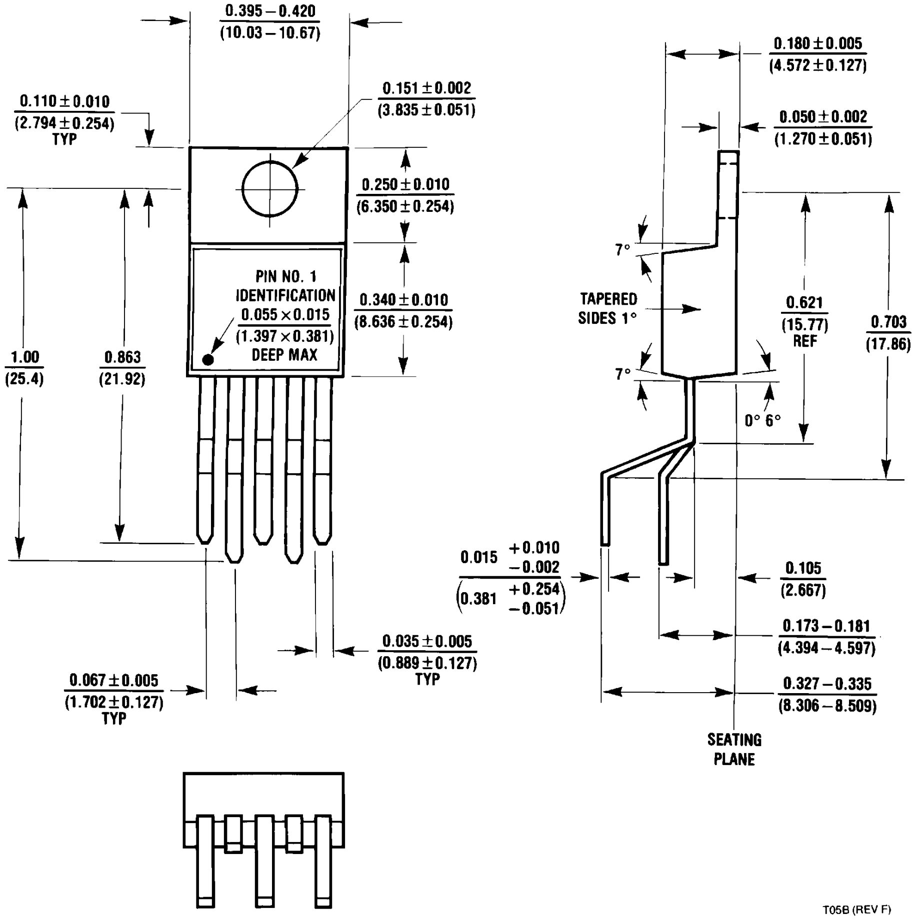
TL/H/5030–6

Single Supply



TL/H/5030–7

Physical Dimensions inches (millimeters)



TO-220 Power Package (T)
Order Number LM1875T
NS Package Number T05B

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform, when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.